WIDENING AND DEEPENING QUESTIONS IN WEB-BASED INVESTIGATIVE LEARNING

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ABSTRACT

Web allows learners to investigate any question with a great variety of Web resources, in which they could construct a wider, and deeper knowledge. In such investigative learning process, it is important for them to deepen and widen the question, which involves decomposing the question into the sub-questions to be further investigated. This corresponds to creating a learning scenario that implies the questions and their sequence to be investigated with Web resources. The learning scenario would be useful for the learners to reflect on the constructed knowledge. However, it is quite difficult for them to create their own scenario concurrent with knowledge construction from the contents of the resources. How to scaffold the learning scenario creation is an important issue as Web-based investigative learning aid. Towards this issue, we have modeled Web-based investigative learning process, which induces learners to create the learning scenario by decomposing a question into the sub-questions while searching and navigating the Web resources. In this model, the learning scenario is represented as a tree of questions investigated. This paper also demonstrates an interactive learning scenario builder iLSB we have implemented. iLSB provides scaffolds for the learners to build the tree of questions in learning with Web resources. The results of the case study suggest that iLSB makes learner-created scenarios more structured, and that it allows the learners to promote their reflection on knowledge constructed during investigative learning process.

KEYWORDS

Web-base investigative learning, question decomposition, navigation, knowledge construction, scaffolding, learner-created scenario

1. INTRODUCTION

Web allows learners not only to search the information necessary for learning, but also to investigate any question with a great variety of Web resources (Land 2000). However, existing Web resources are not always well-structured and reliable for learning (Kashihara and Akiyama 2013). The learners accordingly need to select and navigate the Web resources/pages and to integrate and reconstruct the contents learned at the navigated resources/pages by themselves (Henze and Nejdl 2001). Such Web-based investigative and navigational learning process allows them to construct their own knowledge in a wider, and deeper way (Jonassen 2000, Land 2000).

In investigating a question with Web resources for the knowledge construction process, it is important for the learners to deepen and widen the question. It corresponds to finding out related questions to be further investigated during their navigation and knowledge construction process, which can be viewed as the sub-questions. In this way, the investigative learning process involves decomposing the initial question into the sub-questions. Wider and deeper decomposition of the initial question would make the investigative learning process more structured and fruitful (Kashihara and Akiyama 2013). The initial question would be also defined with the question decomposition.

Instructional textbooks, on the other hand, usually provide learners with the scenario like table of contents, which implies the questions and their sequence to be learned/investigated. The learners could follow the scenario to investigate the questions. Web resources, however, do not always provide such scenario. It is accordingly necessary for the learners to investigate a question during navigating Web resources/pages, and to find out the sub-questions for constructing wider and deeper knowledge, which corresponds to creating their own scenario in a question-driven way (Hill and Hannafin 1997, Jonassen

2000). Such learner-created scenario would be useful for them to promote their knowledge construction process and to reflect on their constructed knowledge after investigative learning process.

But, it is quite difficult for the learners to create their own scenario concurrent with navigation and knowledge construction with the Web resources. Since they tend to pay more attention to the navigation and knowledge construction process for investigating a question (Hill and Hannafin 1997), they often miss finding out the sub-questions to be further investigated, which results in an insufficient investigation.

How to promote decomposing a question while navigating Web resources to scaffold the learning scenario creation is an important issue as investigative learning aid. Towards this issue, we have proposed a model of the investigative learning process, which induces the learners to decompose the question into the sub-questions to define the question (Kashihara and Akiyama 2013). In this model, the learning scenario is represented as a tree of questions investigated.

In this paper, we demonstrate an interactive learning scenario builder (iLSB for short) we have implemented. iLSB allows the learners to build their own scenario during investigative learning process and to reflect on their constructed knowledge with the scenario after investigative learning process. This paper also reports a case study with iLSB where investigative learning with iLSB is compared to investigative learning with Web browser. The results suggest that the learner-created scenario allows the learners to construct their knowledge in a more structured way, and that it allows them to promote reflection on their knowledge constructed.

2. MODEL OF WEB-BASED INVESTIGATIVE LEARNING

2.1 Learning Phases

We have proposed a model of investigative learning with Web resources as shown in Figure 1, which includes three cyclic phases: (a) search for Web resources, (b) navigational learning, and (c) learning scenario creation (Kashihara and Akiyama 2013, Kinoshita and Kashihara 2013).

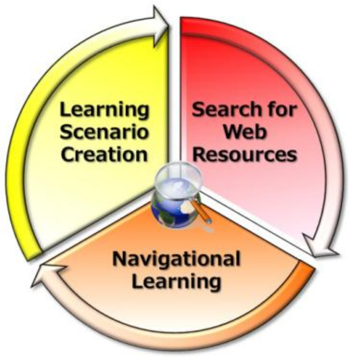

Figure 1. Model of Web-based Investigative Learning Process

In the phase (a), learners could use a search engine such as Google with a keyword representing the initial question to gather the Web resources suitable for investigating it, and navigate across these resources. Such keyword is called q-keyword. In the phase (b), they are then allowed to navigate the Web pages in these resources to learn the contents and construct knowledge. Such knowledge construction with navigation is called navigational learning (Kashihara and Hasegawa 2005). In the navigational learning process, the learners are expected to extract keywords representing the contents learned from the navigated pages to make their relationships for representing their knowledge constructed.

In the phase (c), the learners are expected to find out a number of sub-questions to be further investigated, which corresponds to decomposing the initial question into the sub-questions. The sub-questions could be chosen as sub q-keywords from the keywords extracted in the phase (b). Each of the sub-questions could be

also investigated in the next phases (a) and (b). These three phases are repeated until the question decomposition does not occur.

The question decomposition results in the tree called question tree including part-of relations between question and the sub-questions, which corresponds to the learning scenario. The root of the tree represents the initial question in the investigative learning process. Creating the scenario corresponds to defining the initial question, which would be essential for Web-based investigative learning (Kashihara and Akiyama 2013). The scenario created would prevent the learners from getting lost in hyperspace provided with Web resources since it can allow them to refer to the information on what and how questions have been investigated so far (Hill and Hannafin 1997, Jonassen 2000). After investigative learning process, it also allows them to reproduce their knowledge construction process and to reflect on their knowledge constructed. Without the scenario, it would be difficult to understand how their knowledge has been constructed.

2.2 Related Work

In general, it is not so easy to succeed in investigative learning process on the Web. In the phase of searching for Web resources, search engine with a q-keyword is not always enough to find out and navigate across Web resources fruitful for learning it. A promising approach to this issue is to prepare a repository including Web resources related to the topics investigated, in which the resources are well interrelated (Brusilovsky and Henze 2007, Henze and Nejdl 2001). There is another social approach to building a repository of Web resources where these are collected and indexed within a learning community so that the navigation and knowledge construction process could be promoted (Dieberger and Guzdial 2003). Such repositories allow learners to search and navigate across Web resources in a more efficient and fruitful way.

In the phase of navigational learning, it is particularly difficult to self-regulate navigation and knowledge construction processes concurrent with understanding the contents of the Web pages visited. Adaptive hypermedia technologies (Brusilovsky 2001) could contribute to resolving this issue although it is necessary to adjust these technologies so that they could work even on unstructured Web resources. We have been also developing cognitive tools as scaffolds for learners to self-regulate navigational learning process even in unstructured hyperspace (Kashihara and Hasegawa 2005, Kashihara and Taira 2009, Kashihara and Ito 2012). In particular, we have focused on planning and reflecting on navigational learning process as self-regulation activities.

In the phase of learning scenario creation, the question decomposition process tends to be implicit, and often gets stuck since the learners tend to pay more attention to learning the contents of the Web resources/pages. The created scenario would be then simply structured, and would result in poor investigation. How to make the question decomposition process wider and deeper to scaffold creating better scenario is an important issue as investigative learning aid (Kashihara and Akiyama 2013). There is little related work on scaffolding for learner-created scenario as far as we know. We have been accordingly addressing the issue of how to scaffold learning scenario creation by seamlessly combining the three cyclic phases.

3. iLSB: INTERACTIVE LEARNING SCENARIO BUILDER

3.1 Framework

We have developed iLSB, which is implemented as an add-on for Firefox (Kashihara and Akiyama 2013). iLSB provides learners with the following scaffolds to reify the investigative learning process as modeled.

- **Page browser** (Web browser) with **search engine**,
- **Keyword repository** for storing keywords representing the contents learned, and
- **Question tree** representing part-of relations between q-keywords.

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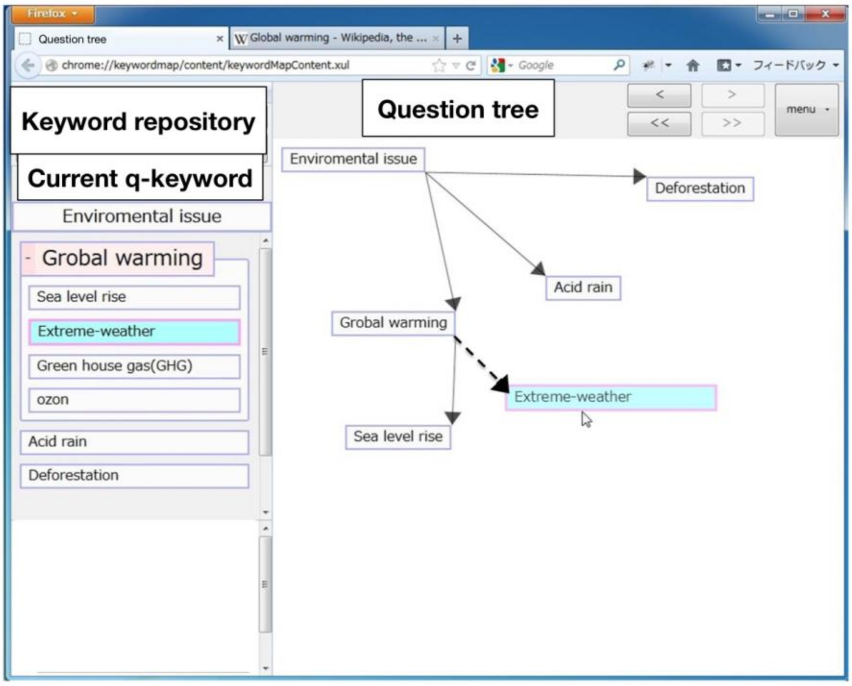

Figure 2. User Interface of iLSB

Figure 2 shows the user interface of iLSB. The page browser and the question tree are displayed as tabbed pages on Firefox. The keyword repository is also displayed in the left-side bar.

iLSB first allows the learners to input an initial question as q-keyword, which is then located in the root of the question tree. They would then use the search engine with the q-keyword to select and navigate across the Web resources suitable for investigating the question. The learners are allowed to browse the Web pages to extract keywords from the browsed pages, which represent the contents learned about the question. The keyword repository allows them to store the extracted keywords to make relationships among them for representing their knowledge constructed although iLSB currently limits the relationships to inclusive one for classifying the keywords. In the keyword repository, the learners could become aware of some keywords insufficiently learned or crucial for investigating the question, which should be further investigated. They are then allowed to mouse-drag the keywords to drop them as sub q-keywords on the tree and to make the part-of relations from the root. The learners are next expected to investigate these sub-questions by means of the three scaffolds.

When a q-keyword in the tree is mouse-clicked, it becomes the current question investigated. The keyword repository also changes the current q-keyword synchronously, which displays the keywords extracted in investigating the current q-keyword. In other words, each q-keyword has its own sub-repository for storing the keywords extracted.

3.2 Scaffolding

In building a question tree as learning scenario, the tree and keyword repository work together. Let us here consider how to scaffold the question tree building with an example where a learner investigates a question about what *Environmental issue* is.

iLSB first puts the q-keyword *Environmental issue* initially inputted by the learner on the root of the tree. The learner is then allowed to search with it for Web resources to extract the keywords such as *global warming*, *sea level rise*, and *extreme-weather* from the page of *Global warming* as shown in Figure 3. The pages from which the keywords are extracted are automatically linked to the keywords in the repository. When the learner mouse-clicks a keyword in the repository, he/she can display the linked page in the page browser to review the contents learned about it.

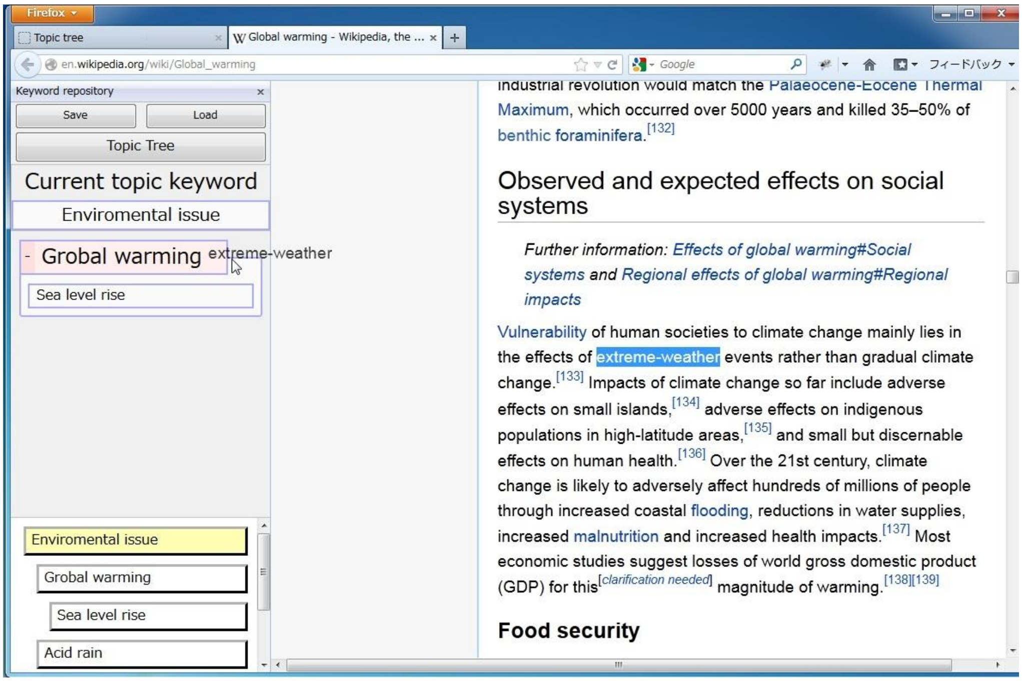

Figure 3. Keyword Repository in iLSB

The learner is also allowed to make inclusive relations among extracted keywords in the keyword repository. In Figure3, he/she makes an inclusive relation between *global warming* and *extreme-weather* by mouse-dragging the keyword *extreme-weather* in the page browser onto the keyword *global warming*. Since the current q-keyword is displayed in the repository, it would be easy for the learner to identify the question for which the displayed keywords are extracted. In Figure 3, *global warming*, *sea level side*, and *extreme-weather* are the keywords extracted for investigating the current question about *Environmental issue*.

The question tree is displayed in the tabbed page. When the learner finds out another question to be further investigated in the keyword repository, he/she is allowed to mouse-drag the corresponding keyword to drop onto the tree. In Figure 2, the keyword *extreme-weather* is mouse-dragged and dropped as new q-keyword onto the map, to which the learner would make a part-of relation from the q-keyword *Global warming*. Each q-keyword in the tree also embeds a link to the Web page where it is extracted. Mouse-clicking a q-keyword, the learner can review the contents learned about it anytime in the page browser as the tabbed page. Since the current q-keyword changes to the clicked question, he/she can also take a look at a number of keywords extracted for it in the keyword repository. In addition, the learner can change/delete the part-of relations in the tree if necessary.

In this way, iLSB allows the learners to make their learning scenario creation process explicit, which would make the investigative learning process more structured.

4. CASE STUDY

4.1 Purposes and Procedure

We have had a case study whose purposes were to ascertain whether iLSB could promote question decomposition to make investigative learning process more structured and whether learning scenario built with iLSB could contribute to reflecting on knowledge constructed in comparison to ordinary Web browser.

The participants were 14 graduate and undergraduate students in science and technology who had more than 3 years experience in Web use. We set two conditions, which were (a) investigative learning with iLSB

(iLSB-group), and (b) investigative learning with Firefox (Browser-group). We assigned 7 participants per condition.

This study included 2 experiments referred as Experiment I and II. In Experiment I, each participant was required to carry out investigative learning, and was informed that he/she was later required to make a paper on knowledge learned. The participants in iLSB-group could use the log (the question tree and keyword repository) generated with iLSB for making the paper. The participants in Browser-group were required to take notes including the keywords for the topic and the contents learned in regard to each keyword while using Firefox, and could use the notes for the paper. In Experiment II, each participant was then required to use the log generated in Experiment I to build a table of contents (TOC) for the paper on knowledge learned in Experiment I.

In Experiment I, each participant in iLSB-group was first given an explanation about the investigative learning model and about how to use iLSB, which intended to instruct him/her how to carry out investigative learning with Web resources, but which did not require him/her to promote question decomposition to make scenario more structured. Each participant in both groups was given a simulated task of investigating a question to practice using the assigned tool. The time limit given was 20 minutes. After that, the participant was required to carry out investigative learning with a task of investigating the initial question what *environmental issue* is. He/she was also provided with 19 Web resources to be searched by means of Google custom search engine, which we selected as informative ones for this initial question in advance. The time limit was one hour. In addition, he/she was informed that 3 days later he/she was required to make a paper on knowledge learned in this investigative learning process.

In Experiment II, each participant was required to make a TOC including a hierarchy of sections for making the paper on knowledge constructed within 15 minutes. He/she was allowed to look at the log generated in Experiment I (question tree and keyword repository for iLSB-group, and notes in regard to keywords/contents learned for Browser-group).

4.2 Results and Consideration

In order to ascertain whether iLSB could make investigative learning process more structured, we compared learning scenario created in Experiment I. As for Browser-group, the experimenters extracted the q-keywords and their part-of relations from each participant's note to estimate the question tree representing his/her learning scenario. In case question tree becomes wider and deeper, the investigative learning process would be more structured.

We used the following data to analyze the question tree:

(1) Number of q-keywords included,
(2) Depth of the tree
(3) Number of leaf q-keywords, and
(4) Degree of question decomposition

The degree of question decomposition (QD) represents to what degree a question is decomposed, and it is calculated for each q-keyword except root and leaf q-keywords as follows: **QD(i) = d * m**, where QD(i) is defined as QD of q-keyword *i*, *d* is defined as the distance from the root to *i*, and *m* is defined as the number of q-keywords included in the sub-tree of *i*. In Figure 2, for example, QD (*Global warming*) is calculated as **1(=d) * 2(=n) = 2**. The q-keyword that is located at a deeper level and that is decomposed into more sub-questions (descendant q-keywords) has a higher QD. In evaluating QD of the tree, we use maximum QD that is the maximum of QD (i) and average QD that is the average of QD (i).

Table 1 shows the results of learning scenario analysis. From the results of one-sided t-test, there were significant differences between iLSB-group and Browser-group in the averages of the data (1) to (4) ($t_{(12)}$=2.05, p<.05 for (1); $t_{(12)}$=1.61, p<.10 for (2); $t_{(12)}$=2.05, p<.05 for (3); $t_{(12)}$=1.68, p<.10 for (4) Maximum QD; and $t_{(12)}$=1.46, p<.10 for (4) Average QD). These results suggest that iLSB-group could make the learning scenario and investigative learning process more structured.

In addition, we have ascertained to what extent unrelated/improper q-keywords were included in question tree generated. The average ratios of unrelated/improper q-keywords in learning scenario were 0.05 (for iLSB-group) and 0.01 (for Browser-group). This suggests that almost all q-keywords in the learning scenario are related and proper to the questions investigated. We have also ascertained that the number of Web pages browsed and use of search engine. The average numbers of browsed pages were 36.1 (for iLSB-group) and

38.9 (for Browser-group). The average numbers of search engine use were 11.0 (for iLSB-group) and 10.9 (for Browser-group). There were no significant differences between the two groups in these averages. This result suggests that iLSB does not seriously impede operations necessary for investigative learning process.

Table 1. T-test analysis for learning scenarios

	(1) Number of topic keywords	(2) Depth of tree	(3) Number of leaf keywords	(4) QD	
				Maximum	Average TD
iLSB-group	18.7 *	4.43†	11.4 *	8.71†	4.91†
Browser-group	9.86	3.29	6.00	3.29	2.75

one-sided t-test, *: p<.05, †: p<.10

In order to ascertain whether learning scenario built with iLSB could promote reflecting on knowledge constructed, we next compared TOC of the paper made in Experiment II. In case TOC includes more q-keywords in the learning scenario, and is structured with the q-keywords, the reflection process would be promoted.

We used the following data to analyze the TOC:

(5) Number of sections/sub-sections in TOC,

(6) Degree of section decomposition

(7) Precision, which was the ratio of keywords used in TOC to q-keywords used in learning scenario, and

(8) Recall, which was the ratio of q-keywords to keywords used in the sections/sub-sections.

As for (6), we regard TOC as tree of sections, and define degree of section decomposition (SD) in the same manner as QD. The maximum and average SDs are also defined in the same manner as QD.

Table 2 shows the results of TOC analysis. From the results of one-sided t-test, there were significant differences between iLSB-group and Browser-group in the averages of the data (5) to (8) ($t_{(12)}$=1.87, p<.05 for (5); $t_{(12)}$=1.77, p<.10 for (6) Maximum SD; $t_{(12)}$=2.59, p<.05 for (6) Average SD: $t_{(12)}$=1.60, p<.10 for (7); and $t_{(12)}$=2.44, p<.05 for (8)).

The results of (5) and (6) suggest that iLSB-group could make the paper contents more structured. From the results of (7) and (8), in addition, iLSB-group uses more q-keywords in the learning scenario to reconstruct TOC. This suggests that reflection process on knowledge constructed in investigative learning could be promoted.

Table 2. T-test analysis for TOC of papers.

	(5) Number of section/sub-sections	(6) SD		(7) Precision	(8) Recall
		Maximum	Average		
iLSB-group	21.6 *	10.3†	5.20 *	74.1†	58.1*
Browser-group	16.6	5.86	3.13	59.0	39.4

one-sided t-test, *: p<.05, †: p<.10

Following the above analysis, we ascertained the potential of iLSB. On the other hand, we also observed some participants who built the question trees less decomposed. In order to make such question trees wider and deeper, it is accordingly necessary for iLSB to provide not only the question tree but also some aids for promoting the question decomposition.

5. CONCLUSION

This paper has demonstrated iLSB that provides learners with scaffolds for creating their learning scenario for investigative learning on the Web. The learning scenario creation process is viewed as decomposing a question into the sub-questions to build a tree of questions investigated.

This paper has also reported the case study. The results suggest that iLSB makes investigative learning process more structured, and that it allows the learners to promote reflection on knowledge constructed. We have been also aware of some learners who still have difficulties in creating their learning scenario with

iLSB. We have accordingly been addressing this issue with the attribute presentation method, in which iLSB provides the learners with the attributes depicting the part-of relations between questions (Kinoshita and Kashihara 2013). These attributes could promote the question decomposition, and induce the learners to create a wider and deeper scenario.

In future, we will conduct more detailed evaluation with iLSB to refine the scaffolds provided by iLSB.

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